Volume 16 DECEMBER 10, 1941 Number 7

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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAMME OF THE

ANNUAL MEETING

AT

PRINCETON UNIVERSITY

PRINCETON, NEW JERSEY

December 29–31, 1941

PUBLISHED BY THE AMERICAN PHYSICAL SOCIETY
SEVEN ISSUES EACH YEAR

The American Physical Society

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AMERICAN PHYSICAL SOCIETY

Published seven times per year

Subscription price: $5.00 per year

Single copies: $1.00 each

The Bulletin of the American Physical Society is published seven times a year during the months of February, April, June (2 issues), November (2 issues), and December at Prince and Lemon Streets, Lancaster, Pa.

Address correspondence to Prince and Lemon Streets, Lancaster, Pa., or to Secretary Karl K. Darrow, Columbia University, New York, N. Y.

Entered at the post office at Lancaster, Pa., as second class matter.

Acceptance for mailing at a special rate of postage provided for in the Act of October 3, 1917, embodied in paragraph 4, Section 412, P. L. & R., authorized April 28, 1928.

DECEMBER 10, 1941 Vol. 16, No. 7

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AMERICAN PHYSICAL SOCIETY

ANNUAL MEETING, PRINCETON, NEW JERSEY

December 29–31, 1941

THE **43rd Annual Meeting of the American Physical Society,** being the 246th of the regular meetings, will be held on Monday, Tuesday, and Wednesday, December 29, 30, and 31, 1941, at Princeton University, Princeton, New Jersey. The **American Association of Physics Teachers** will be meeting there on Monday and Tuesday, and certain of the activities will be in common. The Physical Society will have its sessions for contributed papers in Palmer Laboratory, the first commencing at two o'clock on Monday afternoon.

A **registration desk** will be set up in Palmer Laboratory, and it is requested that members register at their earliest convenience.

Hotels. The Princeton Inn and the Nassau Tavern offer rooms at $3 per night single and $5 double. Reservations should be made as early as possible, by letter to the hotel selected; members should write that they belong to the Physical Society. Members are reminded that it is the practice of hotels not to hold reservations into the evening hours, unless specifically so requested (with an indication of the presumptive hour of arrival of the guest).

A **seminar on theoretical physics** will be arranged for Monday evening (commencing at 8:15) by the Institute for Advanced Study at its building. There will be speeches by Professor A. Einstein and Dr. W. Pauli. Professor Einstein will speak "On Solutions of Finite Mass of the Gravitational Equations," and Dr. Pauli on "Problems of the Quantum Theory of Fields."

The **business meeting** of the Physical Society will be held in Room 301 of Palmer Laboratory on Tuesday at 2 P.M., and will be followed by a joint session of the American Physical Society and the American Association of Physics Teachers at which the following papers will be presented:

PRESIDENT G. W. STEWART: **Liquid Structure.** (*Retiring presidential address of the American Physical Society.*)

PROFESSOR W. F. MAGIE: **Joseph Henry.**

PROFESSOR A. H. COMPTON: **War Problems of the Physics Teacher.** (*First Richtmyer Memorial Lecture of the American Association of Physics Teachers.*)

The **Council** will meet at 2 P.M. on Monday in Room 114 of Fine Hall (adjacent to Palmer Laboratory).

A **reception and tea** for members and guests of the two societies will be given by Princeton University at the Graduate College from 4:30 to 6 o'clock on Monday afternoon.

Ladies attending the meetings are invited to a buffet luncheon on Tuesday at 1 o'clock in the home of Mr. and Mrs. Henry De Wolf Smyth.

The **dinner** of the two societies will be held in the Nassau Tavern on Tuesday evening at 7 o'clock, at a price of $1.80 including tip. Dinner tickets will be for sale at the registration desk, and must be bought before 11 o'clock on Tuesday morning.

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The annual luncheon for Sigma Pi Sigma members and guests, held in connection with the Christmas meetings of the A.A.P.T. and the Physical Society, is scheduled for 12:15 on Tuesday, December 30, in the Ranger Room of the Nassau Tavern. The luncheon will be concluded in ample time for the afternoon sessions. Tickets for the luncheon, at $1 each, must be purchased at the physics registration desk before 10 A.M. Tuesday. Advance reservations with the Executive Secretary of the Society would be appreciated as the number which can be accommodated is limited.

General Rules Relating to Papers

By vote of the Society on December 27, 1940, no paper may be accepted for presentation at any meeting of the Society unless the title and an abstract of the paper are delivered to the office of the American Physical Society not later than the closing date stated in the printed call for that meeting.

The time allowed for the oral presentation of a contributed paper is ten minutes at most.

When two or more papers are contributed by the same member, all but one are placed on the "supplementary programme." (A paper by two or more members is credited to the one first named in its title.) For each paper on this programme the Secretary indicates a session at which it may be presented. The presiding officer at this session may call for it when the other papers are completed, may require that it be given in shortened form, or may read it by title.

Titles and abstracts of the papers to be presented are given in the following pages. Proofs of these abstracts have not been submitted to the authors. After submission of proof the abstracts will be published in an early number of *The Physical Review*.

Other meetings are planned as follows:

245. December 19–20, 1941. Pacific Coast Meeting. Stanford University, California.
247. February 20–21, 1942. Detroit, Michigan.
248. April 30, May 1 and 2, 1942. Place either Baltimore or New York.
249. June 17–20, 1942. Pacific Coast Meeting. Salt Lake City.
250. June 25–27, 1942. State College, Pennsylvania.

Sectional Meeting. The Secretary of the Southeastern Section of the Physical Society notifies us that its annual meeting is to be held on April 10–11, 1942 in Oxford, Mississippi at the University of Mississippi.

Karl K. Darrow, *Secretary*
Columbia University, New York, New York.
December 10, 1941.

CALENDAR

Monday afternoon, December 29

2:00 o'clock: Palmer Laboratory: Room 301: Session A. Papers 1–11 (and supplementary programme Paper 43 if chairman so rules). See pages 6–8 and 15.

2:00 o'clock: Fine Hall: Room 114: Meeting of the Council of the Physical Society.

4:30 o'clock: Graduate College: Reception and tea given by Princeton University.

Monday evening, December 29

8:15 o'clock: Institute for Advanced Study: Seminar on theoretical physics: Speakers —Professor A. Einstein and Dr. W. Pauli. See page 8.

Tuesday morning, December 30

10:00 o'clock: Palmer Laboratory: Room 301: Session B. Papers 12–22. See pages 8–10.

10:00 o'clock: Palmer Laboratory: Room 307: Session C. Papers 23–33 (and supplementary programme Paper 44 if chairman so rules). See pages 10–12 and 15.

Tuesday afternoon, December 30

2:00 o'clock: Palmer Laboratory: Room 301: Annual Business Meeting of Physical Society.

2:30 o'clock: Palmer Laboratory: Room 301: Joint Session with A.A.P.T. Addresses by Professor G. W. Stewart, Professor W. F. Magie, and Professor A. H. Compton. See page 13.

Tuesday evening, December 30

7:00 o'clock: Nassau Tavern: Joint dinner with A.A.P.T.

Wednesday morning, December 31

10:00 o'clock: Palmer Laboratory: Room 301: Papers 34–42. See pages 13–15. To be read by title: Papers 45 and 46. See page 16.

PROGRAMME

MONDAY AFTERNOON AT 2:00 O'CLOCK

Palmer Laboratory—Room 301

Session A

1. Association Effects in the Raman Spectra of Thiophenol Solutions. FORREST F. CLEVELAND, M. J. MURRAY, AND ROBERT H. SAUNDERS, *Illinois Institute of Technology.*—Since the S−H vibration gives a sharp, intense line in the Raman spectrum, as contrasted to the broad, diffuse bands arising from the O−H vibration, it seemed quite suitable for use in an investigation of association effects. Consequently, Raman spectra were obtained, using solutions of one cm³ of thiophenol in three cm³ of the solvents, benzene, dioxane, pyridine, acetophenone and di-isobutyl ketone, with equal exposure times and comparable development. With benzene solution, the S−H line at 2570(9) cm^{-1} was sharp and appeared at the same frequency and intensity (if allowance is made for the smaller concentration) as in pure thiophenol. With acetophenone, di-isobutyl ketone and pyridine solutions the line still appears at the same frequency, but is now very broad and has intensities of *5*, *3* and *1*, respectively, while with the dioxane solution two maxima were observed at 2569(2) and 2542(½). The results for the pyridine solution are in direct contrast with infra-red data[1] in which the S−H band was found to be shifted 114 cm^{-1} to lower frequencies, while the intensity *increased* several fold.

[1] Gordy and Stanford, J. Am. Chem. Soc. **62**, 500 (1940).

2. The Near Ultraviolet Absorption Spectrum of Monodeuterobenzene. C. A. BECK, *The Catholic University of America*, AND H. SPONER, *Duke University.*—The near ultraviolet absorption spectrum of monodeuterobenzene from 2270–2680A has been photographed in the first order of a 5-meter grating spectrograph. The spectrum resembles closely that of light benzene. The bands at 38640.8 ($A°_0$) and 37520.8 ($B°_0$) are assigned to the 0−1 and 1−0 transitions of the $603\epsilon^+_g$ vibration. This yields 517 cm^{-1} for the value of this ϵ^+_g vibration in the upper state. The 0,0 band is calculated to be 38123.8 and it occurs very faintly. Compared to light benzene, the $A°_0$ is shifted by 30 cm^{-1}, and the 0,0 band by 34.4 cm^{-1} from the calculated 0,0, both to the violet. As compared to heavy benzene, $A°_0$ is shifted by 149.4 cm^{-1}, and the 0,0 band by 167.8 cm^{-1} from the calculated 0,0, both to the red. Similar to benzene, bands appear displaced to the red from the main bands 603−517=86 cm^{-1}. The frequency difference of 160 cm^{-1} found in light benzene remains unchanged. The totally symmetrical carbon vibration appears in progressions with separations of 912 cm^{-1} as compared to 923 cm^{-1} in light and 879 cm^{-1} in heavy benzene. Other bands were explained corresponding to assignments in light and heavy benzene.

3. Fine Structure of the Infra-Red Bands of C_2H_6. LINCOLN G. SMITH AND W. M. WOODWARD, *Princeton University.*—The bands of C_2H_6 have been studied under higher resolutions than previously[1] in the temperature range from 175°K to 300°K. From the structure of the fundamental $\parallel$ band at 1379.0 cm^{-1} (which structure is clear only at low temperatures), and that of harmonic $\parallel$ bands at 2753.3 cm^{-1} and 2369.3 cm^{-1} a value of $(42.25\pm0.05)\times10^{-40}$ gm cm^2 has been obtained for the large moment of inertia A. A single $\perp$ band with an anomalous decrease of both intensity and line spacing in the center (about 1484) has been observed in the 1480 cm^{-1} region. In the $\perp$ band at 827 cm^{-1} a peak of lower intensity about midway between each of the main peaks has been resolved. The intensities of these minor peaks decrease toward the center of the band and apparently increase relative to the major peaks as the temperature is lowered. $C=11.06\times10^{-40}$ gm cm^2 is calculated from the three active $\perp$ fundamentals by taking for the 1484 cm^{-1} band $\Delta\nu=5.20$ cm^{-1} which is the regular spacing of the lines at the sides of the band. This, together with $C-C=1.54\times10^{-8}$ cm,[2] gives $C-H=1.11\times10^{-8}$ cm and the tetrahedral value for all angles. The harmonic bands have all been studied but no new definite evidence has yet been obtained concerning the assignment of the degenerate fundamental frequencies. A complete report on this work will be published in the near future.

[1] Levin and Meyer, J. Opt. Soc. Am. **16**, 137 (1928); Bartholomé and Karweil, Zeits. f. physik. Chemie **B39**, 1 (1938).
[2] Pauling and Huggins, Zeits. f. Krist. **A87**, 205 (1934); Pauling and Brockaway, J. Am. Chem. Soc. **59**, 1223 (1937).

4. Pressure Effects on Spectral Lines. H. M. FOLEY* AND D. M. DENNISON, *University of Michigan.*—The intensity distribution in a spectral line due to interactions with neighboring atoms or molecules has been derived from the expressions for the growth of states, as in the quantum theory of radiation. The translational motion was treated classically, and the atomic interactions were introduced as time dependent perturbations. The adiabatic solution gives the well-known Fourier integral expression of Lorentz and Weisskopf. To the approximation that the duration of the collisions is small compared with the time interval between collisions (low density), the treatment of the interaction may be limited to the phase shifts appearing in the Fourier integral. With this approximation the line shape has been calculated, and it is shown that the phase changes alone will produce a shift of position as well as a broadening of the spectral line. The ratio of shift to broadening depends on the force law of the atomic interaction, and in particular upon the presence or absence of resonance interaction. The duration of the collisions has been taken into account as a next approximation, and the calculated line form shows typical asymmetry. Applications have been made to the

self broadening and foreign gas broadening in molecular spectra.

* Chas. A. Coffin Fellow 1941–42.

5. The Calculation of the Magnetic Susceptibility of H_2, HD, and D_2 by Quantum Mechanics. ENOS E. WITMER, *University of Pennsylvania.*—The molar magnetic susceptibility χ_M of H_2, HD, and D_2 is given by a formula which may be written briefly as $\chi_M = -A+B$, where A is the diamagnetic term. Using the eleven-term wave functions of James and Coolidge, together with a Morse wave function for vibration, the value of A comes out to be 4.115×10^{-6} for H_2, 4.099×10^{-6} for HD, and 4.080×10^{-6} for D_2. Although B was calculated from wave functions also, the best value of B appears to be the value 0.093×10^{-6}, which was obtained by N. F. Ramsey from experimental data. Using this value, χ_M is -4.022×10^{-6} for H_2, -4.006×10^{-6} for HD, and -3.887×10^{-6} for D_2. Due to an approximation in the process of averaging by the Morse wave function, the values of A and therefore of χ_M are good to only three significant figures, but the differences are good to the third decimal places as written here. Summing up the experimental results, E. C. Stoner in his book gives χ_M for H_2 as $-4.00\pm0.05\times10^{-6}$. The calculated results above have a higher degree of accuracy, the uncertainty being less than $\pm0.035\times10^{-6}$.

6. On the Heisenberg Theory of Ferromagnetism. P. R. WEISS, *Harvard University.*—The second of the Heisenberg approximations, based on the assumption of a Gaussian distribution of the energy levels belonging to a given value of the spin of the crystal about the mean value, leads to serious difficulties. As pointed out by Van Vleck, there is an error in Heisenberg's calculations of the mean square energy which makes his results invalid except in the case where the spin per atom is one-half. Moreover, it is found in this case that the second approximation leads to a low temperature critical point so that it predicts zero magnetization at very low temperatures. In this paper, the third and fourth moments of the energy are calculated for the general lattice assuming the spin per atom to be one-half. An expression for the critical temperature is obtained in the form of a series in descending powers of the coordination number. It is found that the values of the critical temperature and of the discontinuity in specific heat at the critical point obtained by including the successive moments converge satisfactorily. The calculations are also made for the case where the spin per atom is one and comparisons are made with the experimental results for iron and cobalt.

7. Strong Coupling Mesotron Theory of Nuclear Interactions. S. M. DANCOFF AND W. PAULI, *Institute for Advanced Study.*—We consider the results of the assumption of a strong coupling between nuclear particles and mesotrons of spin zero, treating the heavy particles as fixed sources of finite radius. Previous investigations* have indicated that this theory can account for the small scattering of cosmic-ray particles. They have also resulted in the prediction of excited states, or isobars, of the proton-neutron, differing in charge from the fundamental states. We here extend the treatment to the case of charged pseudo-scalar mesotrons; the appearance of the heavy particle spin in the formalism in this case gives ground for hope that nuclear forces may be properly described. This theory again results in heavy particle isobars; in this case, however, the isobars differ with respect to spin as well as charge, and the energy separation depends quadratically on spin and charge excesses.

* See, particularly, J. R. Oppenheimer and J. Schwinger, Phys. Rev. 60, 150 (1941).

8. On a Field Theory of Nuclear Forces. JULIAN SCHWINGER, *Purdue University.*—Mesotron theories of nuclear forces based on perturbation methods have suffered from the grave defect that the tensor forces which they predict possess inadmissible $1/r^3$ singularities. Although the concept of strong coupling, applied to the pseudo-scalar theory, is remarkably successful in accounting for cosmic-ray phenomena; it does not remove the objectionable singularities. If, however, in addition, a vector mesotron field is postulated which possesses the same nuclear coupling constant as the pseudo-scalar field, but whose particles differ in mass from the pseudo-scalar mesotrons observed in cosmic-rays, the inadmissible singularities are removed. The sign and magnitude of the resultant tensor interaction, which behaves as $1/r$ at small distances, is determined by the mass difference of the two mesotrons. It is satisfactory that the positive quadripole moment of the deuteron corresponds to the vector mesotron being more massive than the pseudo-scalar mesotron, for such particles will be highly unstable against disintegration into a pseudo-scalar mesotron and a γ-ray; and thus would not have been observed. However, the spontaneous disintegration of the vector mesotrons formed at the top of the atmosphere will provide a source of soft component to be added to the soft component production by the β decay of the pseudo-scalar mesotrons.

9. Theory of Nuclear Coulomb Energy. EUGENE FEENBERG, *New York University.*—A symmetry argument, similar to that applied by Wigner to the problem of nuclear mass defects, yields the following expressions for the Coulomb energy:

$$E_c=\frac{Z}{8}\{4(Z-1)L_c-(Z-4)L'_c\}$$

for even values of Z, and

$$E_c=\frac{Z-1}{8}\{4ZL_c-(Z-3)L'_c\}$$

for odd values of Z. The quantities L_c and L'_c are matrix elements involving the Coulomb interaction, the space coordinate exchange operator and the isotopic spin operators. It is assumed that L_c and L'_c are constant in an isobaric series and vary smoothly with n, the total number of particles. These assumptions make possible the determination of L_c and L'_c as functions of n. Numerical results and applications will be presented.

10. Theoretical Half-Lives of Beta-Transitions. C. L. CRITCHFIELD, *Harvard University.*—The results of Konopinski and Uhlenbeck[1] on the energy distribution of beta-particles in forbidden transitions have been integrated in order to determine the relation between half-life and maximum energy in such transitions. It is assumed that $Z \ll 137$. Estimates of the matrix elements which appear in the five different interactions are made for intramultiplet transitions and compared with the experimental results on Na^{22}, Sc^{42}, P^{30}, Cl^{34} and K^{38}. It appears that all of these radioactivities may be first forbidden and that the interaction between the field of the nuclear particles and that of electron and neutrino must contain the product of tensor operators (tensor-interaction) or of pseudo-scalar operators or of both. Thus, possible assumptions for an interaction between the fields include the tensor and the antisymmetric interaction.[2]

[1] E. J. Konopinski and G. E. Uhlenbeck, Phys. Rev. **60**, 308 (1941).
[2] C. L. Critchfield and E. Wigner, Phys. Rev. **60**, 412 (1941).

11. Lifetimes for Forbidden Transitions in β Decay and Orbital Electron Capture and Spins of Nuclei. R. E. MARSHAK, *University of Rochester.*—A general formula giving minimum lifetimes for forbidden β transitions of arbitrary order or forbidden orbital electron capture is derived. Exact Coulomb wave functions are used for the electron. It is shown that the observed electron emission of K^{40} requires Gamow-Teller selection rules. Combined with the Konopinski-Uhlenbeck[1] result that only the tensor and vector interactions are compatible with the energy spectra of the β-rays from Na^{24}, P^{32} and RaE, it follows that the tensor interaction alone can explain both the lifetimes and energy spectra of forbidden β transitions. The application of the tensor interaction to K^{40} and to the other long-lived β emitters, Rb^{87}, Lu^{176}, Be^{10}, C^{14}, and to existing data on orbital electron capture, leads to certain spin and parity predictions about parent and product nuclei—e.g., neither Be^{10} nor C^{14} can have a spin greater than $3h$, the 2 Mev γ-ray from K^{40} is associated with s-electron capture to an excited state of A^{40} having even parity, etc. The stability of the known neighboring isobars and the conditions under which p-electron capture becomes more probable than s-electron capture will also be discussed.

[1] E. J. Konopinski and G. E. Uhlenbeck, Phys. Rev. **60**, 308 (1941).

MONDAY EVENING AT 8:15 O'CLOCK

Institute for Advanced Study

Seminar on Theoretical Physics

I. On the Solutions of Finite Mass of the Gravitational Equations. A. EINSTEIN, *Institute for Advanced Study.*

II. Problems of the Quantum Theory of Fields. W. PAULI, *Institute for Advanced Study.*

TUESDAY MORNING AT 10:00 O'CLOCK

Palmer Laboratory—Room 301

Session B

12. Elementary Explanation of Thermal Diffusion. W. H. FURRY, *Harvard University.*—A successful elementary explanation of thermal diffusion was first given quite recently by Frankel,[1] who accounted for the existence of the phenomenon for molecules which differ in mass, and for its dependence on the intermolecular force law. Frankel's idea may readily be extended to explain the appearance of the effect for molecules which differ only in radius, and also gives a result similar to that of the mathematical theory for the effect of the quantum-mechanical difference in cross-section for collisions between identical and non-identical molecules.[2] It may also be extended to explain the appearance of transport due to thermal diffusion, as well as the stationary case considered by Frankel. Simple considerations can be used to give a correct estimate of the value of the thermal diffusion constant.

[1] S. P. Frankel, Phys. Rev. **57**, 661L (1940).
[2] Effect first suggested by H. M. Mott-Smith.

13. Isotope Separation Factor of a Thermal Diffusion Column. RALPH SIMON, *Yale University.*—A hot wire type of Clusius and Dickel column was operated at various pressures for wire temperatures of 1100°K and 1500°K. In each case, after equilibrium had been obtained, the separation factor was measured by taking off samples of the gas (argon) at the top and bottom of the column and analyzing them with a Nier type mass spectrometer. The theoretical variation of the separation factor with pressure was

verified and experimental values of the constants in the thermal diffusion theory of Furry, Jones, and Onsager were obtained. Running the column under conditions of turbulent flow produced only a slight, if any, decrease in the separation factor determined by extrapolation from the data obtained under conditions of lamellar flow.

14. Difference in Loss of Energy of Deuterons in D_2 and H_2. C. M. CRENSHAW, V. J. YOUNG, H. P. MANNING, *New York University.*—The energy loss of deuterons in D_2 and H_2 has been measured as a function of energy from 60 kev to 340 kev. A path length of 18.4 cm at 2 mm Hg pressure of gas was used for these measurements. Preliminary work indicates the loss to be linear with respect to pressure up to 3 mm Hg.

Incident energy	Loss in H_2	Loss in D_2	Difference
60 kev	18 kev	15 kev	3 kev
120	17	14	3
180	15	12	3
240	13	10	3
300	11	9	2
340	9	8	1

15. Evidence for *p*-Wave Proton-Proton Scattering. EDWARD C. CREUTZ AND ROBERT R. WILSON, *Princeton University.*—The accuracy in the measurement of the angular distribution of 8 Mev protons scattered from the hydrogen in cellophane foils has been improved. The yield appears to be somewhat greater at small angles than would be expected for a pure *s* scattering anomaly. This suggests the presence of some repulsive scattering of the *p*-wave. Thus the cross-section per unit solid angle is independent of angle from 20° to 45° with an accuracy of 2½ percent. At 45° where the effect of the *p*-wave vanishes,[1] the observed cross-section in the laboratory system is $1.7\pm0.1\times10^{-25}$ cm², in good agreement with the value 1.75×10^{-25} cm² calculated by BTE[2] on the assumption of a square potential well of depth 10.5 Mev and width e^2/mc^2. The largest source of error in the measurement of the absolute yield is the uncertainty in the composition of cellophane. This difficulty will be discussed.

[1] True on the assumption of a central field. See Breit, Kittel, and Thaxton, Phys. Rev. **57**, 255 (1940).
[2] Breit, Thaxton, and Eisenbud, Phys. Rev. **55**, 1018 (1939).

16. On the Relative Probability of the D,2*n* and the D,*n* Reactions in Ni and Zn. J. M. CORK, L. N. HADLEY, JR., AND C. V. KENT, *University of Michigan.*—Only a very few elements offer any possibility for studying the relative probability of the D,2*n* and the D,*n* reactions. One of these elements is copper in which a 7.9 min. activity has been ascribed to Cu 60 and a 3.4 hr. activity to Cu 61. Since nickel 60 has an abundance of 27.2 percent and nickel 61 only 0.1 percent, the yield of these two copper radioactivities should tell the relative probability for the D,2*n* and the D,*n* reactions. Now by reducing the energy of the incident beam a change in the relative yield would be expected. Actually, the relative yield was found to be independent of the bombarding energy and hence indicates that the previous assignment is incorrect. A similar result is obtained in bombarding zinc and observing the radioactivity in gallium. Gallium 66 and 67 had been considered as radioactive isotopes of half-lives 9.4 hr. and 83 hr., respectively, and hence could both be made from Zn 66. Actually the relative yield of each was found to be independent of the bombarding energy, indicating that they are probably isomers. The gamma-radiations from the 83-hr. zinc have been studied in the magnetic spectrometer, giving energies of 93.6, 181, 300, and about 600 kev.

17. Radioactive Selenium from Arsenic. C. V. KENT, J. M. CORK, AND W. G. WADEY, *University of Michigan.*—Arsenic has a single stable isotope of mass 75. When bombarded with deuterons this can form selenium 75 by a (D,2*n*) reaction or selenium 76 by the (D,*n*) process. A single activity whose half-life is 160 days is observed in the selenium from this bombardment. When studied in a magnetic beta-ray spectrometer of high resolution, many electron groups, corresponding to internally converted gamma-rays, are observed. For energies below 300 kev, at least 8 gamma-rays are observed and for several of them, the $K-L$ difference and the relative conversion coefficients are given.

18. Radioactive Isotopes of Lanthanum. KATHERINE E. MOUNCE, M. L. POOL, AND J. D. KURBATOV, *Ohio State University.*—A radioactive isotope of lanthanum with a half-life of 19 ± 2 hr. is produced by bombardment of barium with 10 Mev deuterons. The radiation consists almost entirely of x-rays which were found by critical absorption measurements to be the characteristic x-rays of barium. Thus nearly all of the active lanthanum decays by the process of *K* electron capture. Bombardments of cesium with 20 Mev alpha-particles and of lanthanum with fast neutrons do not reproduce the activity which therefore seems best assigned to La^{137}. Hilger H. S. lanthanum has been bombarded with deuterons and with slow neutrons for the purpose of investigating the discrepancies of previous reports[1,2,3] on the period of La^{140}. The activity produced in the lanthanum fraction by deuterons was followed through 11 half-lives, giving a period of 40 hrs. This same period was produced by the slow neutron bombardment. The radiation consists of beta-rays and gamma-rays of approximately 1.2 Mev as determined by absorption methods.

[1] J. K. Marsh and S. Sugden, Nature **136**, 102 (1935).
[2] M. L. Pool and L. L. Quill, Phys. Rev. **53**, 437 (1938).
[3] O. Hahn and F. Strassmann, Naturwiss. **28**, 543 (1940).

19. A Study of the Radiations from the Disintegration of I^{130} and I^{131}. J. R. DOWNING, M. DEUTSCH, AND A. ROBERTS, *Massachusetts Institute of Technology.*—The radiations from I^{130} (12.6 hr.) and I^{131} (8*d*) have been studied by spectrometer and coincidence techniques. The disintegration of I^{131} consists of a beta-ray spectrum of energy 0.595 Mev[1] which is now shown to be simple, followed by a 367 kev gamma-ray.[2] A gamma-ray of $80=1$ kev has been shown to be present by critical absorp-

tion of gamma-gamma coincidences. The beta-ray spectrum of $_{4}I^{130}$ is found to be complex, consisting of two groups whose endpoints are 0.55 and 1.07 Mev. Four gamma-rays of energies 0.417, 0.535, 0.670, and 0.740 Mev are known.[2] Coincidence methods confirm the complexity of the beta-ray spectrum, and show also that all the gamma-rays are in cascade. The results are consistent with the assignment of the 0.535 Mev gamma-ray to the transition between the levels on which the beta transitions end. The higher energy spectrum includes 40 percent of all the beta-rays.

[1] M. Deutsch, Phys. Rev. **59**, 940A (1941).
[2] M. Deutsch and A. Roberts, Phys. Rev. **60**, 362 (1941).

20. Gamma-Rays from Long Period Activities. M. DEUTSCH, A. ROBERTS, AND L. G. ELLIOTT, *Massachusetts Institute of Technology.*—Gamma-ray spectrometer studies[1] have been extended to several long lived activities. Accuracy of the energy determinations (about ±3 percent, or better) and the energy range investigated (above 0.18 Mev) are generally about the same as in the previous report.[1]

Gamma-ray Energies

Isotope	Period	Gamma-rays (Mev)	Remarks
Ag^{106}	8 d.	0.505, 1.06, 1.63, 0.72(?)	2, 3
Ag^{106}?	45 d.	0.282, 0.345, 0.430, 0.650, >1.0	3
$Ag^{108 \text{ or } 110}$	225 d.	0.650, 0.925, 1.51	
In^{116}	54 min.	0.428, 1.12, 1.31, 2.32	4
Zn^{65}	250 d.	1.14	5
$Fe^{59 \text{ and } 55}$	>47 d.	1.10, 1.30	
Co (Fe+*d*)	long	0.119, 0.131, 0.847, 1.26, 1.75(?), 3.42	6

[1] M. Deutsch and A. Roberts, Phys. Rev. **60**, 362 (1941).
[2] The 0.5 Mev ray may be annihilation radiation.
[3] In fair agreement with Enns, Phys. Rev. **56**, 872 (1939).
[4] Compare Curtis and Richardson, Phys. Rev. **53**, 942 (1938).
[5] Only a trace of annihilation radiation.

21. Isomeric States in Indium^{112}. R. N. SMITH, *Purdue University.*—Silver bombarded with alpha-particles and indium by fast neutrons yield a pair of isomeric activities for which the growth of the lower activity resulting from the decay of the upper can be directly observed. Chemical identification assigns both states to indium^{112}. Application of the formula for growth of one radioactive state from another gave half-lives of 16.5±2 minutes for the upper and 17.5∓2 minutes for the lower level. The soft conversion electrons from the gamma transition between states were detected with a thin window electroscope and their energy estimated, giving a gamma-ray energy of 120±15 kev. Both positrons and electrons were detected from the decay of the lower state, the positrons with a maximum energy of 1.3±0.1 Mev and the electrons 0.47±0.1 Mev. Another group of particles assumed to be conversion electrons from a 95±10 kev gamma-ray was associated with the lower state. This pair of activities replaces the 20-minute period previously obtained from alpha-particle bombardment of silver and assigned to indium^{110} or indium^{111}, but is distinct from the 23-minute period obtained from deuterons on cadmium.[1]

[1] J. L. Lawson and J. M. Cork, Phys. Rev. **57**, 982 (1940).

22. The Temperature Dependence of Slow Neutron Resonance Absorption in Silver. T. M. SNYDER, J. W. KEUFFEL,* J. J. GILVARRY, AND K. WAY,† *Princeton University.*—The width and cross-section at resonance of the 2.5-volt neutron capture level of silver are obtained from its slow neutron "self-absorption" cross-sections at 25°C and −72°C. The self-absorption cross-section is determined by a comparison of the activities induced in detectors of two thicknesses. By averaging the activity of a detector over various positions inside a large paraffin block which contains the neutron source, the activity due to an isotropic distribution of neutrons is obtained. These activities are corrected for β absorption in the silver and are now being corrected for activities induced by capture into higher levels. For accurate interpretation of results, a theory of the resonance activation of thick detectors is given which takes into account self-reversal with Döppler broadening. The shape of a resonance absorption level and the activities produced by both collimated and isotropic neutrons are given. These calculations permit a more accurate analysis of the slow neutron measurements of previous workers as well as our own.

* Now at California Institute of Technology.
† University of Tennessee.

TUESDAY MORNING AT 10:00 O'CLOCK

Palmer Laboratory—Room 307

Session C

23. Absorption of Thorium on Tungsten Single Crystals. MYRON H. NICHOLS, *Princeton University.*—Electron projection tube studies of the emission from single crystal tungsten wires onto which thorium has been evaporated from a thoriated tungsten source have shown that thorium is absorbed mainly on the (111) and (001) surfaces—i.e., on the surfaces closely surrounding the normal emergence of the (111) and (001) crystal directions. Emission patterns from large single crystals grown in specially doped thoriated tungsten show the same absorption properties as the pure tungsten onto which thorium has been evaporated. These observations agree with those obtained by Daniel[1] from a study of field emission patterns from thoriated tungsten single crystal points and from pure tungsten single crystal points onto which thorium was evaporated.

[1] J. H. Daniel, M.I.T. Doctor's thesis, June, 1940.

24. The Ferromagnetic Anisotropy of an Fe-Al Alloy. SIDNEY SIEGEL, *Westinghouse Research Laboratories.*—Single crystal bars of an Fe-Al alloy containing 4.1 percent Al were prepared by slow solidification of the melt in a vacuum furnace inductively heated. The crystals are cylinders 3 cm in diameter, up to 10 cm long. The orientation of the crystal is determined by x-rays. Disks about 2 cm in diameter, 0.1 cm thick were prepared with their planes parallel to either (100) or (110) crystallographic planes. The ferromagnetic anisotropy constant K_1 was determined by placing the disk in the gap of an electromagnet producing fields up to 3300 oersteds, and measuring the component of magnetization in the disk, J_n, perpendicular to the direction of the applied field H, as a function of the angle θ between a ⟨100⟩ direction in the disk and H. The value for K_1 for this alloy was found to be 3.9×10^5 ergs/cm^3. Several Fe-Si crystal disks, of Si content between 3 and 4 percent, were measured in the same apparatus and gave results in agreement with previous data. It appears that the rate of decrease of K_1 with increasing Al content is smaller than that for Si.

25. A Calculation of the Increase in Electrical Resistance Produced by Cold-Work. JAMES S. KOEHLER, *Westinghouse Research Laboratories*, AND FREDERICK SEITZ, *University of Pennsylvania.*—A calculation of the increase of the specific electrical resistance produced by cold-work has been made using Taylor's dislocation theory. It was assumed that the total specific electrical resistance can be written as

$$\rho=\rho_{\text{thermal}}+\rho_{\text{plastic}}$$

where ρ_{thermal} is the resistance resulting from thermal oscillations of the atoms and ρ_{plastic} is the resistance produced by the internal strains in a cold-worked material. It was also assumed that ρ_{thermal} is proportional to the mean square of the thermal atomic displacements and that ρ_{plastic} is proportional to the mean square of the atomic displacements resulting from the presence of dislocations in a cold-worked metal. It was further assumed that the two constants of proportionality are the same. The results of the calculation for severely cold-worked polycrystalline materials are given below:

	Cu	Ni	W
$\left[\frac{\rho_{\text{plastic}}}{\rho_{\text{thermal}}}\right]_{\text{calc.}}$	4.9%	5.3%	17.8%
$\left[\frac{\rho_{\text{plastic}}}{\rho_{\text{thermal}}}\right]_{\text{obs.}}$	3%	8%	34%*

It is found that the resistance produced by cold-work increases approximately linearly with the density of dislocations.

* See Schmidt and Boas, *Kristallplastizität*, p. 214 (1935).

26. Electronic Structure and Polymorphism of Iron Alloys. R. SMOLUCHOWSKI, *General Electric Company.*—Purest obtainable iron has up to the melting point a cubic body-centered crystal lattice with the exception of a short range of temperatures where it is cubic face-centered. It is well known that additions of various elements forming binary solid solutions with iron influence the range of existence of these two crystal lattices in various ways. This influence appears to be connected with the position of the elements in the periodic system. An explanation of this phenomenon is suggested on the basis of the structure of electron bands. Substitution of other atoms in the place of iron atoms in the lattice changes the electron density at the top of the Fermi distribution, affecting the specific heat, the energy and stability of both crystal forms. In the case of interstitial alloys with carbon, nitrogen, etc., the mechanism is somewhat different. This model helps also to understand the polymorphism in ternary solid solutions where the influence of various elements follows a simple additive law. Various facts can be explained qualitatively on the basis of the suggested model.

27. Hall Effect in Cuprous Oxide. S. J. ANGELLO, *University of Pennsylvania.*—Measurements of the Hall effect and conductivity of cuprous oxide have been made on samples prepared as follows: Copper of known purity was oxidized completely in air at 1000°C. The oxide was annealed 2 hours at a lower temperature, and quenched in water immediately. It is found that the Hall constant and conductivity do not obey the exponential laws of temperature dependence for temperatures above about 80°C. The precise value of this temperature depends on the annealing conditions. The deviation from the exponential law of the Hall constant is related to the disappearance of lattice defects. The rate of diffusion of defects can be increased by an electric field when the temperature is 100°C. The deviation of the conductivity from the exponential law is due not only to diffusion of lattice defects, but also to a rapid decrease of the mean free path with increasing temperature. The measurements have been carried to approximately 100°C.

28. Resistivity of Antimony-Tin Single Crystals at Low Temperature. C. T. LANE AND W. A. DODD, *Yale University.*—The electrical resistivity of pure antimony and alloys of antimony and tin in the form of single crystals has been investigated from room temperature down to the temperature of liquid helium. All measurements were made with the direction of the current perpendicular to the principal crystal axis, and for various amounts of tin up to about 3 atomic percent. It is found that the average temperature coefficient of resistance between 4.2°K and 77.3°K decreases sharply with increasing tin content assuming a small constant value at 3 atomic percent. While the addition of tin at room temperature changes the resistivity very little, the effect at 4.2°K is very large. This "residual" resistivity is approximately a parabolic function of the tin concentration. Comparison of these results with the Bloch theory of metals is made.

29. Remark Concerning Liquid Specific Heats. GREGORY H. WANNIER, *University of Iowa.*—The wave type of normal mode analysis has been extended recently from the solid to the liquid.[1] Because of disorder, liquid modes possess a stronger coupling and equipartition is not main-

tained. Lucas tried to estimate this effect by assuming the correctness of the viscosity concept for all waves. This makes the specific heat much too small, because viscous resistance becomes paramount for all transverse and the shorter longitudinal waves. It is more natural to assume that the liquid possesses instantaneously solid rigidity, but that the stress decays with a half-period computable from viscosity data. The liquid is then quasi-solid for wave-lengths shorter than 10^{-7} cm. For mercury, one finds the specific heat 10 percent below $3R$, tending to decrease with temperature. This agrees with observation. The treatment cannot apply in its present form near the critical point. However, Lenz[2] has shown that even gases may be treated by vibrational analysis if the change in nature of the sound velocity is observed. Thus it is probable that a unified theory of specific heats applicable to all three phases can be developed.

[1] René Lucas, Jour. de Phys. **10**, 60 (1939).
[2] Arnold Sommerfeld, Probleme der freien Weglänge. From *Vorträge über die kinetische Theorie*, Teubner, 1914.

30. Atomic Images with the Electron Microscope. L. I. SCHIFF, *University of Pennsylvania.*—Some of the conditions that must be satisfied in order to obtain an electron microscope image of the arrangement of the atoms in a molecule are discussed. It is shown that in typical cases the minimum aperture angle of the objective lens is not much less than the angle at which elastic scattering begins to fall off rapidly and is about equal to the greatest angle at which inelastic scattering is appreciable, independently of the velocity of the electron. Thus in the usual transmission microscope many of the scattered electrons will enter the objective lens and the image will show poor contrast. This difficulty can be overcome by inclining the axis of the condenser lens with respect to that of the rest of the microscope, so that the undeviated beam just misses the objective aperture. Then only scattered electrons enter the objective, and the problem of obtaining sufficient contrast is replaced by the more straightforward one of obtaining sufficient intensity. This method of "dark field" illumination appears to be superior to that which employs annular stops in the condenser system, since the necessarily very small objective aperture angle and scattering angle require the use of exceedingly well collimated condenser beams.

31. Nerve Fiber Impedance. KENNETH S. COLE, *Columbia University.*—A nerve fiber is similar to a submarine cable in that it has a low resistance interior with a high resistance capacitative membrane at the surface. The impedance characteristics of the membrane may be calculated by cable theory from measurements made between well-separated long electrodes surrounding each end of a single fiber. Such measurements have been made on the giant nerve fiber of the squid over the frequency range from 10 cycles to 200 kilocycles. The reactance is capacitative, as expected, at the higher frequencies, but it may become zero between 200 and 300 cycles and be inductive for lower frequencies. An approximate equivalent circuit for a cm² of this nerve membrane is found to be a capacity of $1\mu f$ shunted by a resistance of 400 ohms and an inductance of 0.2 henry in series. However preliminary experiments with various external electrolytes show that this circuit is over-simplified.

32. A Comparison of Optical and Electromechanical Methods of Studying Ultrasonic Fields.—WILLIAM GARTEN, *The Johns Hopkins University.*—Statements made regarding the accuracy to be obtained in measurements of ultrasonic velocity and absorption by various methods are not always borne out by the consistency of the results themselves. This is particularly true in the case of liquids in which measurements have often been made with little attention paid to the effects of high intensity, and the accompanying possibility of distortion of measurements produced by heating effects. Such effects produce temperature gradients and give rise to large apparent decrements introducing errors both in velocity and absorption measurements.[1] Observation of ultrasonic fields in liquids by optical methods in the ultrasonic frequency region of 3 megacycles shows that intensities greater than those necessary to produce first order Debye-Lears spectra produce important distortions of the field. Measurements are possible by methods of acoustic interferometry with intensities from one to two orders less than those necessary for the optical methods, and at these low intensities distortions of field due to a possible temperature gradient have not been detected.

[1] J. C. Hubbard, Am. J. Phys. **8**, 219 (1940); Phys. Rev. **59**, 935 (1941).

33. Diffusion of Heat Through a Rectangular Bar and the Cooling Effect of Fins. I. The Steady State. MELVIN AVRAMI, *Columbia University*, AND J. B. LITTLE, *Bell Telephone Laboratories.*—Exact solutions for temperature distribution and heat flow through a rectangular fin are rederived in more general and simple form than previously given. These are studied numerically and graphically, and shown to yield new results not contained in the approximate formulas hitherto used. Except for the factor of thermal conductivity of the fin material, the cooling effect is a function only of the height-width ratio β of the fin, and of a dimensionless "relative boundary resistivity" μ governing the heat loss to the environment. It is shown that, for any value of this boundary resistivity, there is a fairly sharp optimum value of the height-width ratio beyond which further increase in height will not lead to much improvement in cooling effect. This optimum β decreases with decreasing μ until, at a certain critical value μ^* in the neighborhood of 1, it becomes zero. At the critical μ^*, the cooling effect is altogether independent of β, and the presence of the fin is a matter of indifference. Below μ^*, the cooling effect decreases with increasing β, so that the presence of the fin serves merely to insulate the hot plate. This analysis of a single fin is the basis upon which a study of the conditions for optimal cooling by an array of fins will be carried out in a subsequent publication.

TUESDAY AFTERNOON AT 2:00 O'CLOCK

Palmer Laboratory

Room 301

Annual Business Meeting of the American Physical Society

TUESDAY AFTERNOON AT 2:30 O'CLOCK

Palmer Laboratory

Room 301

Joint Meeting of the American Physical Society and the American Association of Physics Teachers

I. **Liquid Structure.** G. W. STEWART, *State University of Iowa*, President of the American Physical Society.

II. **Joseph Henry.** W. F. MAGIE, *Princeton University*.

III. **War Problems of the Physics Teacher.** A. H. COMPTON, *University of Chicago*—Richtmyer Memorial Lecture of the American Association of Physics Teachers.

TUESDAY EVENING AT 7:00 O'CLOCK

Nassau Tavern

Joint Dinner of the American Physical Society and the American Association of Physics Teachers

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WEDNESDAY MORNING AT 10:00 O'CLOCK

Palmer Laboratory—Room 301

Session D

34. The Consumption of the Positive Arc Carbon. H. G. MACPHERSON, *National Carbon Company*.—The consumption of the positive electrode of an arc between solid carbons in air results partly from evaporation and partly from oxidation. The oxidation is operative chiefly on the sides of the carbon, tapering the end of the electrode and thus producing a tip with a diameter $\frac{1}{2}$ to $\frac{2}{3}$ that of the original carbon. The consumption of the flat tip, or crater, however, is due almost entirely to evaporation. The evaporation rate is controlled by the pressure of carbon vapor at the crater surface and the mechanism of diffusion away from it. This diffusion was computed on the assumption that it is similar to that occurring in the evaporation from liquid drops of the same diameter as that of the carbon crater, and it was shown that the linear electrode consumption should be inversely proportional to the crater diameter. This was borne out approximately by measurements of consumption rates made near the overload current. The absolute values of the consumption rates are consistent with the hypothesis that the surface temperature of the positive crater is at or near the sublimation temperature of carbon.

35. Ionization by Neutral Atoms in the 2000 to 8000 ev Energy Range. H. W. BERRY, *Washington University*. (*Introduced by A. L. Hughes.*)—Using the space charge ion detector, ionization by collision of He and N_2 atoms by their own fast neutrals has been studied for energies up to 8000 electron volts. A beam of ions is first formed and accelerated to the desired velocity. After being homogenized by a velocity selector, the beam is neutralized by charge exchange in passing through its own gas. A retarding potential removes any ions remaining unneutralized, leaving a beam of neutral atoms with the velocity of the ions from which it was formed. The neutral beam then enters a space charge ion detector where the ionization takes place. Finally on striking a nickel plate, secondary

electrons are released which serve as a measure of the intensity of the beam. The curves obtained are considered in relation to the method of measurement and interpreted in terms of a relative cross-section.

36. Self-Quenching Geiger-Mueller Counters. PAUL WEISZ, *Bartol Research Foundation of the Franklin Institute.*—The investigations of Montgomery, Ramsay, Rose, Korff and other authors have yielded a very satisfactory picture of the discharge mechanism in counter tubes, and it is found that the difference in action of the "self-quenching" and the classical counter can be explained in terms of the same picture. In experiments with argon/ethyl-ether mixtures of successively greater ether concentration, the transition from the classical to the self-quenching counter mechanism was observed to take place in exactly the manner predicted by the picture arrived at, invoking emission and absorption of ultraviolet photons, and the electron capture phenomena. The nature of the "plateau" should largely be a probability question concerning the absorption of these photons by the polyatomic gas. In agreement with the consequences of this concept, the plateau of the self-quenching counter is found to be somewhat smaller than that of the classical counter, but with suitable mixing ratios plateaus of around 200 volts were obtained without difficulty. With proper care taken especially regarding the completion of the mixing process before filling the counters, very satisfactory tubes can be constructed with great reliability, and complete reproducibility.

37. The Ionization of Individual Cosmic-Rays. W. F. G. SWANN AND PAUL WEISZ, *Bartol Research Foundation of the Franklin Institute.*—Previously, the results of an experiment employing a proportional counter in connection with a telescopic counter arrangement of high resolution power to define the path length of the rays in the proportional counter were communicated. Plotting the number of particles against relative ionization, two distinct primary maxima were found confirming earlier findings of W. F. G. Swann, and W. E. Ramsay, and E. Stuhlinger, the second maximum corresponding to about 1.5 times the ionization of the first. By measuring the distribution in ionization values with and without lead absorber, we have identified the first maximum as belonging to the penetrating rays, the second maximum as being created by the electron component. The same measurements were carried out at two greatly different gas pressures in the proportional counter to ascertain whether the density of the individual "electron avalanches" in the proportional counter may be of influence on the results supplied by the tube. However, identical results were obtained in both cases. Accepting the Bethe-Bloch ionization formula, we find difficulty in interpreting the two so distinct values of ionization for mesotrons and electrons of energies of the usually assumed order of magnitude, as well as the lack of a sharp cut-off of the distribution in ionization which this formula predicts.

38. The Penetrating Power of Extensive Cosmic-Ray Shower Particles at Sea Levels. NORMAN HILBERRY* AND ANN HEPBURN HILBERRY, *University of Chicago.*—To obtain information concerning the nature of the extensive cosmic-ray shower particles at sea level an experiment has been performed determining the variation in the number of such showers observed per unit time as a function of the thickness of a lead shield placed above the counters. Identical shields were placed over each counter unit; the units were shielded from the sides; and, so that they could be tripped only by air showers, the units were placed on the laboratory roof. Two series of measurements were taken, one with an over-all extension of 110 cm, the other of 40 cm. The shower-frequency curves come to a maximum at a shield thickness of 1.25 cm of lead as would be expected and then drop off with increasing thickness. With 10 cm of lead above each unit of a threefold coincidence set the counting rate is cut to about five percent of the zero shield value. This corresponds to a decrease to about thirty-five percent of the initial counting rate for each counter unit, indicating that about one-third of the extensive cosmic-ray shower particles at sea level can penetrate 10 cm of lead.

* On sabbatical leave from New York University.

39. Cloud Chamber Tracks of Heavy Particles at High Altitude. DONALD J. HUGHES,* *University of Chicago.*—During July of this year a series of 5000 cloud-chamber expansions were photographed at an altitude of 15,500 ft. in Peru. The results show a number of tracks with heavier ionization than electrons and with range greater than that of α-particles. The present paper deals only with these more obviously interesting cases, since detailed measurements and analysis of all the data have been delayed. About 15 of the heavy tracks show a measurable curvature in the magnetic field of 1165 gauss, hence allow a more or less accurate mass determination. It is found that approximately half of these slow, heavily ionizing particles are mesotrons, and half protons. One photograph shows a positive-negative pair of slow mesotrons, created in the material of the chamber. Several cases of knock-on electrons supply additional data for mass calculations. The rate of occurrence and range of the slow mesotrons can be compared with that of fast mesotrons to give an estimate of the mean energy at this altitude; the resulting value is markedly less than that at sea level. Complete curvature measurements of the tracks of the fast particles will furnish an interesting check on this estimate.

* Now at Naval Ordnance Laboratory, Washington, D. C.

40. Neutrons Produced by the Cosmic-Radiation at 14,170 Feet Altitude. S. A. KORFF,* *Bartol Research Foundation of the Franklin Institute.*—A series of measurements on the neutrons produced by the cosmic-radiation was carried out on Mt. Evans. The neutrons were detected by proportional counters filled with BF_3. The counters were surrounded by water, so that the neutrons detected should almost all be slow, and also, so that the neutrons detected should mostly have been produced in the water, very few of those generated outside the water reaching the counter. With this arrangement, counting rates were obtained as a function of pulse size, with and without a thin cadmium shield. Next, the neutron counter was operated in coinci-

dence with a shower detecting unit, the geometry and the water being unchanged. This experiment was conducted with and without cadmium. The number of large showers tripping the arrangement was evaluated by causing the neutron counter alone, and then the neutron-shower coincidence, to control a cloud chamber. The results indicate that neutrons are present in some abundance, and their number increases with altitude by a factor of about two per meter of water, and that some of them appear to be generated by a process connected with the soft component, possibly a nuclear photo-effect.

* Now at New York University.

41. The Effect of Changes of Height of Air Mass on Mesotron Intensity. VICTOR F. HESS AND GEORGE O. ALTMANN, *Fordham University*.—The correlation of mesotron ground intensity with upper "air mass temperature" gives a coefficient of -0.4 percent per °C and is almost constant for all layers. This corroborates the view that the temperature effect of cosmic-rays is primarily an effect of atmospheric mass distribution variations.[1] Likewise the height of the position of the center of gravity $\bar{h}$ gives a good correlation (0.7) with mesotron intensity. A coefficient β was computed $=-\partial I/I\partial\bar{h}=17.5$ percent/km change of altitude. Since $\alpha=\partial I/I\partial T_m$ we have $\beta=-\alpha\partial T_m/\partial\bar{h}$. Thus the mean life range of a mesotron $\bar{L}=c\tau_0\gamma=\partial\bar{h}/\alpha\partial T_m=1/\beta$, if we use Blackett's relation $\alpha=\partial\bar{h}/L\partial T$ or $L=\partial h/\alpha\partial T$. Therefore $\bar{L}=1/0.175=5.7\pm0.4$ km, $\tau_0\gamma=1.9\times10^{-5}$ sec. and the mesotron life time at rest $\tau_0=1.5\times10^{-6}$ sec. assuming $\gamma=12.5$ corresponding to mesotrons of 1 Bev mean energy. From $\partial\bar{h}/\partial T_m=-\alpha/\beta$ we also obtain an independent determination of the change of the position of the center of gravity of the air mass with the lower mass temperature which is numerically 22.5 meters/°C.

[1] V. F. Hess and F. A. Benedetto, Phys. Rev. **60**, 610 (1941).

42. Cosmic-Ray Measurements between New York and Valparaiso. EDWARD B. BERRY, S.J., *Fordham University*. (*Introduced by Victor F. Hess.*)—A Compton Model C cosmic-ray meter, aboard the steamship *Santa Ana*, has been in continuous operation since January 10, 1941 between geomagnetic latitude 52° 00′ N and 22° 10′ S. Hourly intensities were averaged over a Greenwich meridian day and the corresponding mean position of the ship determined in geomagnetic coordinates. The daily means were corrected to a standard of 30.00 inches Hg, using as barometer coefficient Gill's[1] value. To correct for mean atmospheric temperature, the data were divided into those obtained at geomagnetic latitudes lower than 17.5°N and S and those at higher latitudes. Departures from five degree mean values were correlated with atmospheric temperature. For high latitudes $\alpha=\partial I/I\partial T=-0.12\pm0.01$ percent per C°, for low latitudes $\alpha=-0.08\pm0.01$, in good agreement with some values obtained by Compton and Turner and by Gill[1] on the Pacific. All corrected data, compared to an arbitrary absolute value of ionization, show a magnetic latitude effect in the Northern Hemisphere of 7 percent and a temperature latitude effect of 1.5 percent.

[1] P. S. Gill, Phys. Rev. **55**, 1151 (1939).

SUPPLEMENTARY PROGRAMME

43. Nuclear Forces in the Strong Coupling Theory.** S. M. DANCOFF* AND R. SERBER, *University of Illinois*.—Although cosmic-ray evidence proves the existence of a strong interaction between mesotrons and nuclear particles, the calculations of mesotron scattering and of nuclear forces made on the basis of mesotron field theories have not given satisfactory results. These calculations have been made on the supposition that the coupling between heavy particles and mesotrons could be regarded as small, a supposition contradicted by the results of the calculations themselves. It has therefore been hoped that the fault lay, not in the structure of the theory, but in the approximations made in its application. The development of the theory for large, rather than small, couplings was begun by Wentzel,[1] and extended by Oppenheimer and Schwinger, who showed that on this basis the small observed mesotron scattering could be understood. However, the nuclear forces resulting from such a strong coupling turn out to be, over most of their range, ordinary forces (non-exchange, non-spin dependent) which are unacceptable since they do not lead to saturation. This can be understood in a general way; for strong interactions the quantum field theory approaches the classical one, and all effects of the exclusion principle consequently drop out. The calculations have been carried out for charged scalar and for neutral and charged psuedo-scalar mesotron fields. However, the argument is of such a general nature that it seems unlikely that any strong coupling theory can lead to suitable forces.

* Now National Research Fellow, Institute for Advanced Study.
[1] G. Wentzel, Helv. Phys. Acta **13**, 269 (1940).
** To be called for after Paper No. 11, Session A.

44. Application of an Electric Model to the Study of Two-Dimensional Heat Flow.* MELVIN AVRAMI AND VICTOR PASCHKIS, *Columbia University*.—The experimental electric model method of solving problems in heat flow, previously described by one of the authors, is here reviewed and applied to the diffusion of heat through a long rectangular bar placed with a long side on a hot plate. The general mathematical solution for this problem has been worked out by the other author in a previous paper.† The model consists of a network of lumped resistances and capacitances so arranged as to simulate the distribution of resistance and heat capacity in the analogous thermal situation. The results on the model are compared with the mathematical solutions for the steady state, heat flow, and

transient state. The agreement, even with fairly crude lumping (i.e., representing the body by a network with a small number of sections), is remarkably good, generally within two percent. An important result is that it is possible, using a representative network with non-uniform sections, to concentrate investigation on the flow in one part of the body without appreciable sacrifice of accuracy.

* To be called for after Paper No. 33, Session C.
† See Abstract no. 33.

PAPERS TO BE READ BY TITLE

45. Energy Distribution of Mesotrons. M. E. Rose, *Bartol Research Foundation.*—Taking into account decay and energy loss according to the Bethe-Bloch ionization formula the energy distribution of vertically incident mesotrons has been calculated for various elevations and under Pb. Assuming mesotron production in a layer 10 percent from the top of the homogeneous atmosphere and with a $E^{-2.9}$ primary energy distribution, the distributions at sea level for various proper lifetimes, τ_0, are compared with observations. A lifetime of 2×10^{-6} sec. gives good agreement with measurements (Blackett, Wilson) although the experimental error and the insensitivity of shape of the distribution to τ_0 do not exclude a τ_0 as much as 3×10^{-6} sec. The distribution and total number of mesotrons at sea level and under Pb thicknesses up to 2 meters have been calculated. The linear decrease of intensity and the calculated absorption coefficient, 3.0×10^{-3} cm^{-1} Pb, are in excellent agreement with the measurements of Wilson and of Pomerantz. The total number of slow mesotrons ($E<E_0$, $E_0<\sim10^7$ ev) as a function of Pb thickness increases rapidly for small thicknesses but at 45 cm Pb a flat maximum is attained. This optimum Pb thickness is virtually independent of the definition of a "slow" mesotron (of E_0). The decline in number of slow mesotrons for large Pb thickness is in accord with cloud-chamber data obtained in this laboratory.

46. On Photometry with the Photoelectric Cell. F. T. Rogers, Jr.,* *The University of Houston, Houston, Texas.*—Over a usefully wide range of steady cathode-illumination values (L) and steady cathode-to-anode potentials (V), the steady current passed by a photoelectric cell may conveniently be expressed as

$$i=L[\alpha(1-e^{-\beta V})+\gamma(e^{\delta V^2}-1)], \qquad (1)$$

where α, β, γ, and δ are suitable constants for a particular photocell and quality of illumination. This expression is especially suited to gas-filled photocells; for vacuum photocells, the γ, δ-term is often negligible. For example, for a certain set-up with a type 921 photocell, the values $\alpha=14$, $\beta=0.35$, $\gamma=43$, and $\delta=0.00015$ were used in Eq. (1) to give i in microamperes when L was in lumens and V in volts. For $L\leq0.06$ lumen and $30\text{ v}\leq V\leq90\text{ v}$, these yielded i/L values within a very few percent (the amount of experimental uncertainty) of the measured values. This precision is adequate for many photometric purposes, and probably does not represent the ultimate of which Eq. (1) is capable.

* With The University of California (1941–1942), on leave of absence.

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